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110 Dr Richardson *on the Frozen Soil of North America.*

On the Frozen Soil of North America. By JOHN RICHARDSON, M.D., F.R.S., &c. Inspector of Naval Hospitals. Communicated by the Author.†

At the meeting of the British Association held at Edinburgh in the year 1834, M. Arago addressed the Committee of Recommendations *on the necessity of more extensive and systematic observations on the temperature of the earth.* In the course of the discussion which ensued, I mentioned the advantages of *correct measurements of the depth of permanently frozen soil* in the northern parts of America, and at the suggestion of the members then present, undertook to apply personally to the Governor and Committee of the Hudson's Bay Company, requesting that they would give directions for mak-

* Mr Wilson exhibited numerous specimens of mosaic, pietra dura, cameos of different ages in pietra dura, and specimens of shell cameos; also of Genoese and Venetian jewellery, Venetian glass, and ruby glass, together with numerous prints and drawings.

† Read before the Wernerian Society, Dec. 12. 1840.

ing the necessary observations as fully as the means available at their several posts would allow. I wrote, accordingly, to the Governor, now Sir John H. Pelly, Bart., stating fully the object in view, and the mode of making the observations; and that gentleman and the other members of the Committee of the Company, with the zeal for the advancement of science for which they have long been distinguished, early in 1835 transmitted copies of my letter to the several chief factors in charge of districts in the fur countries, with instructions for them to comply with the directions therein expressed.

Pits were dug at upwards of fourteen different posts in the autumn and winter following, but the reports of the results did not reach me until the beginning of the present month (November 1840). In the mean time, the inquiry had been rendered more interesting to scientific men in England by Professor Baer's papers on "*The Ground Ice or Frozen Soil of Siberia*," published in the Journal of the Geographical Society for 1838;* and not being aware that my former letter had been acted upon, I again drew up a paper having similar objects in view, which was printed in the Geographical Journal for 1839, together with "Some notes on the best points in British North America for making observations on the Temperature of the Air." Copies of both were transmitted that same season to Hudson's Bay, together with twenty-six thermometers, carefully constructed by Newman. These thermometers were ordered by the council of the Royal Geographical Society, but the governor and committee of the Hudson's Bay Company liberally determined to defray the expense themselves. Unfortunately the greater part of the thermometers were destroyed by accident in the overland journey, and some of the remaining ones were lost in the winter by their *ivory* scales curving and breaking the tubes; a mischance which has not happened to thermometers with metal scales in that country. By these accidents we have been deprived for a time of a knowledge of the mean temperature of the atmosphere in the northern zones of America, and consequently of the means of calculating theoretically the depth of the frozen soil in the different latitudes.

* See also this Journal, vol. xxiv., p. 435, and vol. xxv., p. 417.—*Edit.*

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The "Extracts of letters" printed in the following pages contain all that each observer reports on the state of the pits dug in 1835 and 1836; but although the zeal with which the trials were made cannot be too highly commended, yet it is to be regretted that the reports are in some instances too concisely drawn up, and a few minute but important particulars have been omitted or overlooked.

Professor Baer remarks that, "If we examine ground which contains only very little moisture in a frozen state, it is very difficult to detect the ice, as it forms an extremely thin partition between the single particles of earth. Should the moisture be more considerable before the freezing comes on, we perceive in its frozen state small pieces of ice, wherever the spaces between the particles are large enough to admit of them. These pieces of ice, which look like small crystals, I have particularly noticed between the upper layer of soil which is thawed, and the lower layer in a frozen state." Attention to these remarks will be very useful in examining a pit dug in sandy soil. A thermometer (as in the case of the observations made in the York Factory) plunged into the soil at the bottom of the pit, will preclude mistake, and should it stand above $+32^{\circ}$ F., will shew that the earth in which it is placed is not frozen. The effect of warming at the fire pieces of hard earth chipped up by the pickaxe, may also be tried. On one occasion, when exploring the banks of the Mackenzie, I broke off a piece of a solid stratum by a smart blow of my hammer, and on examining its grain, concluded that it was a very hard sandstone. Having labelled the specimen and deposited it in my pocket, it was shortly thawed by the heat of my body, and I discovered that it was merely sand containing much frozen water in its interstices. The thawing of this stratum causes a constant crumbling of the cliff at the mouth of Bear Lake River.

"The farther we go east" (in Europe and Siberia), says Professor Baer, "the more southerly do we find the limit of perpetual ground ice. It has not been observed in Lapland out of the mountainous districts, nor did I ever hear of it at Archangel, though Herr Schrenk assured me that, on the Petchora, the ground at a certain depth is never free from ice. Humboldt found in the district of Boguslowsk, in Lat. $59\frac{3}{4}^{\circ}$ N., Long. 60° E., at the foot of the Ural Mountains, small pieces of ice at the depth of six feet in summer; but Boguslowsk lies very high. No permanent ice has been found in Tobolsk in 58° N. At Berezov, in 64° N., where Erman found the temperature of the ground, at the depth of twenty-three feet, to exceed ($+1^{\circ}$ R.) $+34.22^{\circ}$ F., a dead body was found in 1821,

which had been buried ninety-two years in a bed of ground ice, shewing no signs of decay; and we learn from Belawski, that the lower parts of the district are never without ice. So that Berezov is probably very near the limit of perpetual ground ice; for it is clear that *peculiarities of soil must have considerable influence in countries which lie near this limit.* Farther east this frozen soil extends much more to the southward. Georgi, in the last century, related that ice remained in the ground throughout the whole year, upon an island in Lat. 52° N., Long. 106° E., in the environs of Lake Baikal." "In the district of Nertchinsk, Lat. 52° , the ground thawed in summer from one to nine feet, according to its exposure to the sun's rays, but beneath this the frost extended to the depth of forty-two feet from the surface, when the intervention of solid rock prevented farther search. On one occasion, Captain Frehse having dug down six feet through the frozen ground, came to pure ice $2\frac{1}{2}$ feet thick, enclosing boulders of different rocks. Still farther east again, the perpetual ground ice is found at a less depth southwards, probably because the neighbourhood of the sea raises the temperature of the soil. Erman, at least, found no ice at Okhotsk." (BAER, Geogr. Journ. vol. viii.)

The observations on the temperature of the atmosphere in North America hitherto recorded, and the course of the line of termination of the forests towards its arctic extremity, indicate that the isothermal lines dip, as in Siberia, to the southward in their course from west to east through the continent, and the reports of the frozen soil detailed below tend to the same conclusion. Indeed, it has long been said that the climate of the north-west coast of America is milder and opener than that of the eastern coast, and the difference of mean temperature in the 57th parallel is stated by Baer to be 18° F.* The observations of frozen soil made on opposite sides of James's Bay are too few to found much upon, especially as they are not supported by reports on the mean temperature of the air, but they seem to denote a milder climate on the east side of that bay than on the west. Were this proved to be actually the case, it might be considered merely as another example of the fact, that the western coasts of continents have milder climates than the eastern ones, but it might also be adduced in support of an explanation which I have elsewhere† endeavoured to give of the cause of the low temperature of the coast of Hudson's Bay, namely, the detention of

* Vide Richardson, *Therm. Obs. Geogr. Journ.* vol. ix. p. 3rd0.

† Appendix to Franklin's Journey, and to Back's Journey in 1833-35.

fields of ice in its neighbourhood for nearly the whole summer, resulting from the form of the land, and the direction of the prevailing winds and currents of the sea.

As to the local influence of soil to which Professor Bæverfjord directs our attention, I have been informed by a gentleman who has had forty years' experience as a practical farmer in England, that when he used *sand* as a covering for potatoes, carrots, or other vegetables, in the winter, the frost penetrated farther than when loam or other earth was used, and that the looser the latter was thrown over the vegetables, the better was the protection it afforded. He remarked, also, that he always found the earth frozen to a greater depth after severe frosts under a beaten footpath in a field, or compact gravel on the highway, than in loose soil.

Fort-Simpson, on the Mackenzie, being nearly in same latitude with Yakutsk ($62^{\circ} 11'$ N., and $62^{\circ} 1\frac{1}{2}'$ N.), is a desirable locality for ascertaining the thickness of the permanently frozen stratum. At the latter place a well has been sunk into the frozen soil to the depth of 382 feet, and the temperature of the earth, which was $+18.5^{\circ}$ F. at some feet below the surface, gradually rose to $+31.9^{\circ}$ F. at the bottom of the well, where the soil was so loose as to require timbering, which it had not done higher up. This gives a rise of temperature equal to one degree of Fahrenheit's scale for every $28\frac{1}{2}$ feet of descent at a place where the mean heat of the year is about $+14^{\circ}$ F.* In Phillips's Guide to Geology, the mean increment of heat is stated to be 1° F. to every forty-five feet of descent from the surface of the earth, which is one-third less quick than the above. At Fort-Simpson the mean temperature of the air is about $+25^{\circ}$ F., and the frozen soil was found to extend at least seventeen feet from the surface. A thermometer was kept at the bottom of the pit for some time, but the register of its indications has not reached me. Mr McPherson not having been made aware of the

* M. Erman (Geograph. Journ. viii. p. 213) states the mean heat at Yakutsk, as deduced from observations made thrice a-day in the year 1827, to be $+18.72^{\circ}$ F. The mean stated in the text, is also from M. Erman's observations, but continued for several years, and was found by drawing the daily curve for the year indicated by the means at the specified hours.—(Geogr. Journ. ix. p. 380.)

Place
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Michi
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Moose
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Long. 80
Rupert
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Long. 70

importance of searching for spiculæ of ice in the looser and dryer subsoil, or of ascertaining and registering its temperature, the depth of the frost cannot be said to be yet perfectly ascertained at that place. I am indebted to him for a register of the temperature of the atmosphere, carefully kept at Fort-Simpson for three years, and for much useful verbal information respecting the Mackenzie, where he has wintered for nearly eighteen years. He is now in this country, and should he return to his old quarters, we trust that he will speedily set the matter at rest as respects that locality.

Pits were commenced at Fort-Chepewyan and Great Slave Lake, but discontinued, I believe, on coming to the rocky strata which lie near the surface, and no reports were made.

Table containing the Geographical Position of the Posts named in the subjoined Report, and the principal facts ascertained.

Places.	District.	Date.	REMARKS.
Woswonaby, Lat. 49° 20' N. Long. 76° 25' E.	Rupert's River district. Interior, elevated ?	Nov. 3, 1835,	A pit dug in the potato-garden to the depth of 7 feet without discovering any frozen soil.
.....	North of Abitibbe Lake,	Jan. 18, 1836,	In an open potato field, 63 paces from the borders of the lake, snow lying 1 foot deep, soil frozen to the depth of 2 feet 3 inches from the surface.
.....		...	In a thick wood 3 furlongs from the lake, snow 2 feet 5 inches. Soil sandy. Soil frozen to the depth of 1 foot 7 in.
.....		...	Potato field half a mile in the woods. Snow 2 feet. Loose sandy soil frozen 1 foot deep.
.....		...	Ten paces from the lake. Soil coarse gravel, frozen to the depth of 2 ft. 8 in.
Michiskam, Lat. 50° 30' N. Long. 76° 40' W.	Rupert's River district. Interior, elevated ?		Soil never permanently frozen; but in the potato field the frost penetrates 3½ feet in the winter, and in the woods only 6 inches. Soil sandy.
Moose Factory, Lat. 51° 15' N. Long. 80° 55' W.	Mouth of Moose River, at bottom of James' Bay,	Sept. 13, 1835,	No frozen soil in a pit dug 12 feet deep, when the influx of water through the gravel put an end to the operation.
Rupert's House, Lat. 51° 26' N. Long. 78° 40' W.	East side of James' Bay, on the coast,	Between Oct. 16 & Nov. 17, 1835,	Several pits dug from 6 to 8 feet deep in banks of sand, shingle, and clay, from 50 to 60 feet high. Much water flowed in.

Places.	District.	Date.	REMARKS.
Rupert's House, Lat. $51^{\circ} 26' N.$ Long. $73^{\circ} 40' W.$	East side of James' Bay, on the coast,	April 28 and 29. 1836,	A pit dug in open ground, exposed to the NW. winds from Rupert's Bay, and 50 feet from the face of the bank. The frozen soil extended 7 feet from the surface. Under a snow-drift 8 feet thick the soil was frozen only 13 inches deep.
Eastmain Lat. $52^{\circ} 19' N.$ Long. $78^{\circ} 40' W.$	East side of James' Bay, Rupert River District, on the coast,	Sept. 1. 1835,	Situation exposed. Dug 7 feet 8 inches in unfrozen soil, and drove a stake through the soft earth 5 feet farther, in all 12 ft. 8 inches. Stopped by the influx of water. (Compare this with the observations at Albany, in same latitude.)
.....		Sept. 18. 1835,	Dug 8 feet 3 inches, until stopped by water, when a stake was driven 7 feet lower. In all 15 feet 3 in. of soft soil.
.....		Sept. 29. 1835,	Stake driven with ease into a swampy piece of ground 12 feet deep.
.....		Feb. 27. 1836,	Pit dug in the burying-ground, inclosed by stockades, when the frost was found to have penetrated 8 or 10 inches into the soil. The snow-drift lay 8 feet deep over the spot.
Albany, Lat. $52^{\circ} 15' N.$ Long. $81^{\circ} 53' W.$	West side of James' Bay near the coast,	Sept. 2. and 3. 1835,	Thawed surface soil 6 inches; 3 feet 7 inches frozen earth; beneath which a brown clay, so hard that it required to be cut with an ice-chisel, cut into 11 inches; in all 5 feet. Query, <i>Was not the clay Mr Corrigan mentions frozen?</i> It would have been desirable to have placed it near the fire to see if it became more plastic.
Green Lake, Lat. $54^{\circ} 17' N.$ Lon. $117^{\circ} 30' W.$	Interior, on a small lake, at least 350 yards above the sea,	Oct. 15. 1835,	A pit dug 15 feet deep, 40 yards from the lake; 2 feet of gravel on the surface; rest compact clay, so hard at bottom that it was impracticable to dig it deeper. Query, <i>Was it frozen? Would it have softened by heat?</i>
Isle à la Crosse, Lat. $55^{\circ} 25' N.$ Lon. $107^{\circ} 53' W.$	Interior, on the shore of a lake. Perhaps 300 yards above the sea,	Oct. 15. 1835,	2 feet gravel and sand and 8 of hard clay, when water flowed into it. Query, <i>Did the water come in at the bottom?</i>
Severn Outpost, Lat. $56^{\circ} 00' N.$ Long. $86^{\circ} 15' W.$	Severn River, west side of Hudson's Bay,	Autumn,	A frozen stratum reached at the depth of 11 feet, in a loose sandy soil, when the surface-water filled the pit.
.....		...	A pit dug 7 feet in another place was filled with water before the frozen soil was reached.

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Places.	District.	Date.	REMARKS.
Severn Outpost, Lat. 56° 00' N. Long. 86° 15' W.	Severn River, west side of Hudson's Bay,	Autumn,	Frozen earth at the depth of 5½ feet in compact blue mud. The frozen stratum was cut into 7½ feet, when a snow storm put an end to the operation. Pit 13 feet deep.
.....	...	...	The river bank is 30 feet high, and on cutting into it, to make a quay, the frost was found extending downwards till it reached high-water mark, at which point the earth was soft, as far as the experimenter could penetrate horizontally.
York Factory, Lat. 57° 00' N. Long. 92° 26' W.	West side of Hudson's Bay, 5 miles from the mouth of Hayes' River,	Oct. 1835,	Surface water solid. New frost to the depth of 8 inches. Soil, blue tenacious mud, with boulders. Pit 30 yards from the river. Thaw 3 feet from surface. The digging into the permanently frozen stratum continued for fourteen days, when the thawed earth was again reached at the depth of 20½ feet from the surface, leaving 17½ feet of permanent frost, beneath which the temperature of thawed mud was found by repeated trials to be + 33° F.
Fort Simpson, Lat. 62° 11' N. Lon. 121° 32' W.	Influx of the south branch of the Mackenzie into the main stream, about 80 yards above the level of the Arctic Sea,	Oct. 19. 1836,	Pit 80 yards from the banks of the river. Soil heavy, sand and clay mixed. Thawed surface soil 10 feet 7 inches. Frozen substratum 6 feet 3 inches. 8 feet more through a loose sandy soil, and a rod thrust 4 feet deeper into the bottom. In all 29 feet. A thermometer kept at the bottom of the pit shewed a higher temperature than one exposed to the air. The mean temperature of October here is about + 23° F. Mean annual heat + 25° F.*

* These facts ascertained partly by verbal communications with the experimenter, Mr Macleod McPherson.

Our previous knowledge of the depth to which the summer thaw penetrates, or the extent of the frozen substratum in North America, was very limited.

At Fort Franklin on Great Bear Lake, the summer thaw, on the 5th of October 1825, had penetrated 21 inches into the sandy platform on which the house was built. The frozen substratum was dug into about 6 feet, but its total depth was not ascertained. Fort Franklin is supposed to stand about 230 feet above the sea-level. The mean heat of the year 1825-6 was + 17.61° F., and of the first ten days of October + 19.4° F. On the 9th of the same month the small lakes were frozen over, and on the 11th, the snow lying on the ground put an end to the further action of the sun on the soil for that season.

July 5, 1826.—On the east bank of the Mackenzie, in Lat. 68° 37' N., a hole was dug in the sandy soil, at the foot of the Rein-deer Hills, to the depth of 3 feet, without reaching the frozen soil.

July 17, 1826.—On an island of the Arctic Sea, Lat. 70° 10' N.; Long. 129° 15' W., composed of sand and slaty clay, the thaw had penetrated scarcely a foot.

July 28, 1837.—In Lat. 70° 50' N., on the coast to the westward of the Mackenzie, Mr Dense found the soil thawed only to the depth of 4 inches.

ROYAL NAVAL HOSPITAL AT HASLAR,
20th November 1840.

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No. 1.—*Extract of a Letter from George Keith, Esq. chief factor, dated Moose Factory, August 8. 1836.*

"Early in the morning of September 13. 1835, two labourers commenced digging a pit on the island of Moose-factory, in an open, dry situation, 170 paces from the bank of the river. The pit was seven feet long by six wide, and the operators penetrated to the depth of ten feet perpendicular without discovering anything remarkable, the soil being a fine, light, sandy-coloured marl throughout. At this stage, however, water began to make its appearance at the bottom of the pit, and, on digging two feet lower, it increased so much as to put a stop to further excavation. During the progress of digging the last two feet, the soil became rapidly mixed with sand and gravel, and, latterly, almost pure gravel without a sign of frost anywhere. In fact, it has been clearly ascertained that the winter frosts, in dry and exposed situations, do not penetrate beyond five and a half feet; and about the skirts of the forest, which is a wet and marshy soil, the depth of the frost does not exceed three feet. Last winter, which was esteemed severe, the thermometer in the shade fell only once to 35° below zero, namely, on the 30th November, the coldest weather we experienced, which was rather singular, as the colds of January, February, or March, are generally felt to be the most intense."*

No. 2.—*Extract of a Letter from chief trader Robert Miles, Esq., dated Ruperts' House, East Maine, June 25. 1836.*

"From the 16th of October to the 7th of November last, several pits were dug from six to eight feet deep, in all of which much water was found. Indeed, in every part of the vicinity of this establishment, which is situated on banks from fifty to sixty feet high, the earth, being of a sandy nature, over beds of gravel, shingle, and clay, is full of water springs.

"On the 28th and 29th of April last, I caused a pit to be dug in a clear piece of ground in the most exposed situation here, being open to the north-west winds from Rupert's Bay, and in this we did not get through the frost until we penetrated exactly seven feet. This pit was distant fifty feet from the face of the bank.

"One hundred and forty-five yards from the above-mentioned pit, I caused a snow-drift within the stockades of the establishment, eight feet deep, to be cut through, and the earth beneath was found to be frozen to the depth of thirteen inches only."

No. 3.—*Extract of a Letter from Mr Thomas Corcoran, clerk, dated East Maine-post, Rupert's River District, September 30. 1835.*

"On the 19th September 1835, a pit was dug in the plantation in a spot not sheltered with wood, willows, or anything else, and where the snow does not lodge at any time to a greater depth than eight or ten

* "Halley's comet seen from the 12th to the 18th of October 1835, after which it was lost sight of during a succession of snowy weather."—G. K.

inches, and consequently as much exposed to the influence of frost as a place can be.

	Feet.	Inches.
Dug with the spade to the depth of	7	8
Pierced with a wooden stake from the point where the use of the spade was left off, owing to water, to the depth of	5	0
No frost or ice discovered to this depth,	12	8

Quality of the Soil.

Feet.	Inches.	
0	3	Loose mould.
0	5	Mixture of whitish loam and sand.
1	3	Pure sand.
2	0	Loam and sand.
2	0	Loam of a lead colour.
0	8	Lighter coloured loam.
1	1	Lead-coloured loam.
7	8	

From the appearance of the earth adhering to the stake, the next five feet was judged to be lead-coloured loam.

"On the 28th September 1835, a pit was dug about a mile to the eastward of the house, in a green bluff of pines, and consequently sheltered from drift.

	Feet.	Inches.
Dug with the spade to the depth of	8	3
Pierced with a wooden stake after the water flowed in,	7	0
No frost or ice discovered to this depth,	15	3

Quality of the Soil.

Feet.	Inches.	
0	4	Light mould.
1	1	Sand.
1	10	Sand and lime.
1	2	Whitish-coloured loam.
3	10	Lead-coloured ditto.
8	3	

The quality of the remaining depth supposed to be loam.

"On 29th September 1835, a stake of twelve feet in length was driven with ease into a small swamp that is tolerably well sheltered, being surrounded with pine trees and within a mile of the house. No ice was discovered at that depth. In this situation the spade could not be used owing to water.

"On the 27th February last, a grave was dug here in the burying ground, which is enclosed by stockades six feet seven inches high, for interring the remains of a poor old woman who unfortunately was frozen to death on the 25th of the same month. In digging this grave it was discovered that the frost had not penetrated into the soil above eight or ten inches, but then the drifted snow lay as high at least as the stockades that surrounded it."

"From the foregoing observations, it may be inferred that the soil in

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this neighbourhood, to the distance of a mile in any direction from the house, is not permanently frozen."

No. 4.—*Extract of a letter from Mr James Kellock sen., dated Michiskam Post, 1st January 1836.*

"I beg leave to inform you that the earth is never permanently frozen in this section of the Honourable Company's territories, but I found that the frost had penetrated to the depth of three and a half feet in the potato-fields during the course of last winter, whereas, in the woods, six inches was as far as it had gone down. The soil in both places is sandy, with a few small stones."

No. 5.—*Extracts of a letter from Mr John Spencer, postmaster, dated Woswonnahy, Rupert's River District, 28th January 1836.*

"I have caused four different places to be dug, 1st, In an open potato-field about sixty-three paces from the border of the lake, the depth of snow measured one foot; the soil is light at the top, and rather inclining to small gravel for nearly a foot, after which it is of a somewhat clayey nature. The wood surrounding it is principally dwarfish pine, with a few silver pines and birches interspersed, and the depth of frozen ground was two feet three inches.

"2d, In a thick wood, about three furlongs from the lake, where the snow lay about two feet five inches deep, and the soil is of a more sandy nature throughout, except a small surface-layer of vegetable matter, the ground was frozen to the extent of one foot seven inches.

"3d, In a potato-field, about half a mile in the woods, the depth of snow was one foot, and the loose and sandy soil was frozen to the depth of one foot.

"4th, On the borders of the lake, about ten paces from the water's edge, the snow was but trifling, and there were bare patches here and there. I chose one of them, and found the ground frozen to the depth of two feet eight inches before we penetrated to the unfrozen soil. The place was very stony and troublesome to dig, and the poor pick-axe had much employment before we discharged it; but, after we got down a little, clay resembling blue marl began to make its appearance. It happened to be a bitter cold day when the men and myself executed the above on the 27th instant, but, for want of a thermometer, I was unable to ascertain the exact temperature, but judge that it might be 25° below zero.

"On the 3d of November last, I dug a pit in the potato-garden to the depth of seven feet, and not finding any symptoms of frost, considered that further pursuit was unnecessary. The weather at that time was uncommonly beautiful, and unlike the rugged weather which we generally experience at this season.

"It may not be unworthy of remark, that there is a strip of open water to be seen on the lake all the winter round, even in the severest

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weather, for the distance of about three miles in the circuitous course it takes to Net Point. This is supposed to be the leading channel to the main river, but no current is perceptible ; the open water must therefore be caused by the nature of that part of the bed of the lake, for the cold at times is sufficiently severe to freeze every thing but an actual cascade."

No. 6.—*Extract of a Letter from chief trader Jacob Corrigal, Esq., dated Albany, 3d September 1836.*

" I beg to inform you, that, in order to ascertain the temperature of the earth at this place, we dug a pit in the course of yesterday and this morning, and found the soil thawed at the depth of five feet, and frozen earth three feet seven inches. The soil at the surface six inches deep of black earth, from that and nearly to where the frozen earth terminates, there was a brownish-coloured clay, so hard that it was not perceived to be thawed earth, till after it was cut about two inches deep with a nice chisel. A few small pieces of shells were found amongst the blue clay."

No. 7.—*Extract of a Letter from Mr Chief Factor R. M'Kenzie sen., dated Isle à la Crosse, 1st June 1836.*

" Two pits were dug 15th October last. One at Isle à la Crosse, thirty yards from the lake, to the depth of ten feet, when water began to come up, two feet of gravel and sand on the top, and eight of hard clay ground. And one at Green Lake, to the depth of fifteen feet forty yards from the lake, two feet of pure sand, and thirteen of clay ground, but so hard at the bottom that it was impracticable to dig it deeper, and no frozen earth to be found. I have heard it frequently said by old servants who have resided here for upwards of thirty years, and who have had occasion to dig pits and graves at all seasons of the year, that they never knew the frost to penetrate into the earth more than from two to three feet deep."

No. 8.—*Extract of a Letter from Mr Chief Trader James Hargrave, dated York Factory, 25th August 1836.*

" At this place the digging of a pit to ascertain the principal facts, commenced in the beginning of October last. The surface water being then completely solid, and any addition to the depth of last summer's thaw being despaired of, as the new frost had already penetrated eight inches into the ground. The spot selected was the driest in the vicinity of this factory, perfectly exposed to all changes of atmosphere throughout the season, and upwards of thirty yards from the bank of the river. The soil is a deep blue tenacious mud. The periodical thaw was soon dug through, and when accurately measured, was found to be exactly three feet from the surface-level to the beginning of the permanent frost. From this point the operation continued for about fourteen days, at the end of which time the thawed earth was again reached, the distance from the surface of the ground being twenty and a half feet, thus leaving a stra-

tum of seventeen and a half feet of perpetual frost. It may, however, be material to remark, that, on close examination, the total depth of the pit was found to approximate very nearly to the height of its mouth above high-water mark in its vicinity, which may lead to a suspicion that the layer of permanent frost might have been thicker had the river bank been higher at the place where the pit was dug. The "blue mud" above noticed was found to extend to the lowest point reached, varied at points from three to five feet asunder by layers of small gravel mixed with solid ice. Each layer about from three to five inches thick. Shells, such as are still found about the shores of the stream, were discovered imbedded in the mud about twelve feet from the surface in a state of perfect preservation; pieces of drift-wood (willow) were dug out about nine feet deep, some of them quite fresh. The temperature of the thawed mud immediately below the permanent frost was ascertained by repeated trials to be $+33^{\circ}$ on Fahrenheit's scale.

"A similar attempt was made last autumn to ascertain the like facts at Severn outpost; but, from various adverse circumstances, the result was not so satisfactory. The first pit was dug through a loose sandy soil, eleven feet deep, at which point the permanent frost was reached. The surface-water, however, filled the pit, and the party being unprovided with adequate means to keep it dry, another attempt was made elsewhere.

"In this second pit, the labours were again interrupted by water, after having dug through seven feet of thawed ground without reaching the frost. A third attempt was made in a close compact soil of blue mud, about twenty yards from the bank of Severn river, in which they reached the permanent frost at the depth of $5\frac{3}{4}$ feet from the surface. The labourers continued cutting the solid frost to an additional depth of $7\frac{1}{4}$ feet when the surface-water, together with a snow-storm, put a stop to further proceedings that season.

"The postmaster, who superintended the undertaking at Severn, mentions that, having occasion to cut into the river-bank (which at that place was above thirty feet in perpendicular height), for the purpose of making a summer quay, he found the frost extending downwards till it reached the mark of high water, below which the earth appeared quite soft and thawed, as far, in a horizontal direction below the frost, as he could penetrate. This circumstance appears to coincide with what was observed at York Factory, and to lead to the conclusion that permanent frost descends to the point where it first meets with the level of water."

No. 9.—*Extract from a Letter from Mr Chief-Trader Murdoch
McPherson, dated Portage la Loche, 4th August 1836.*

"A copy of a letter from Dr Richardson to Governor Pelly, dated Melville Hospital, 25th February 1836, was transmitted to me, together with instructions from Governor Simpson to furnish the information required; but I am sorry to inform you that those instructions did not reach me till late in December, when the ground was so deeply frozen that experiments

of this kind became altogether impracticable for the season ; and the period at which I travelled on the Mackenzie River this spring was too early for the occurrence of recent land-slips or rents in the earth, by which the question might have been resolved. I shall, however, avail myself of the close of the summer to obtain the required information."

No. 10.—*Extract of a Letter from Mr Chief-Trader Murdoch McPherson, dated Fort Simpson, Mackenzie River, 1837.*

"I beg leave to send you the following report of a pit dug at this place on the 19th of last October (1836). The pit was made at the distance of eighty yards from the banks of the river, in a heavy soil of sand mixed with clay, and in a situation free to the action of the sun during the summer. The result was 10 feet 7 inches deep of thawed soil, from the surface of the ground to that which is permanently frozen, and 6 feet 3 inches deep of frozen soil (permanently frozen, as I believe) between that which thaws during the summer and that which never freezes."

On the Cultivation of the Cerealea in the High Latitudes of North America. Comprised in the extract of a Letter from PETER WARREN DEASE, Esq., Chief Factor of the Hudson's Bay Company to Dr RICHARDSON. Communicated by the latter.

THE following extract of a letter from Mr Dease (to whose intrepidity, skill, and intelligence, conjoined with the able assistance of his lamented colleague Mr Thomas Simpson, we owe the completion of the survey of the northern coast of America from Back's River to Behring's Straits) furnishes a further illustration of the nature of the North American climate, and is therefore closely connected with the preceding and following articles.

"In regard to the cultivation of grain on Mackenzie's River, I can only say, that although we had *wheat* in perfection in 1828 from Fort aux Liards (Lat. 60° 5' N. ; Long. 122° 31' W.), that was the only season out of several in which the grain ripened ; and the culture of wheat is reported to be equally precarious at Dunvegan, Peace River (Lat. 56° 6' N. ; Long. 117° 45' W.). Most places lying near the Rocky Mountains are liable to summer frosts, and I observed the same thing during my residence at Fort St James (Lat. 54° 30' N. ; Long. 124° W.) on Stuart's Lake in New Caledonia ; though I understand that at Fort George (Lat. 54° 35' N. ; Long. 125° W.) on Frazer's Lake, and at Alexandria (Lat. 52° 58' N. ; Long. 123° W.) on Frazer's River, good crops of wheat are raised. The whole average about four months in coming to maturity. *Barley* has been cultivated to advantage at Fort aux Liards, Fort Simpson (Lat. 62° 11' N. ; Long. 121° 32' W.), and Fort Norman (Lat. 64° 41' N. ; Long. 124° 45' W.), and generally takes three months to ripen. *Oats* have come to perfection at Fort aux Liards, and at Fort Simpson,

but have not been sown at Fort Norman yet, though no doubt they might thrive as well there as at the two former places, and ripen about a fortnight sooner. I know of no vegetable but the turnip which has been successfully tried at Fort Good Hope (Lat. $67^{\circ} 28' N.$; Long. $130^{\circ} 52' W.$), but that root was far better on the island of the old fort below the ramparts (Lat. $66^{\circ} 18' N.$; Long. $128^{\circ} 32' W.$) than on the more elevated mainbank opposite, where the soil is also more dry. Fort Norman had a tolerably good crop of potatoes, barley, cabbages, &c."

25th Nov. 1840.

Register of the Temperature of the Atmosphere, kept at Fort Simpson, North America, in the years 1837, 1838, 1839, and 1840. By MURDOCH McPHERSON, Esq., Chief Trader of the Hudson's Bay Company; abstracted by JOHN RICHARDSON, M.D., F.R.S., Inspector of Naval Hospitals, Haslar.

FORT Simpson, a post belonging to the Hudson's Bay Company, is situated on the Mackenzie, at the confluence of its south branch, named the River of the Mountains, and 870 miles from the Arctic Sea, in Lat. $62^{\circ} 11' N.$; Long. $121^{\circ} 32' W.$ The fort stands on the west bank of the river, about 40 feet above its channel, and, if we allow 3 inches a mile for the fall of the river from thence to its mouth, the position of the thermometer may be estimated to be about 250 feet above the level of the sea. The temperature was registered in the morning and evening at 8 o'clock, and for two years at 2 p.m. Mr McPherson informs me, that the times of observation were not always exactly adhered to, though, in general, they were very nearly so. With the exception of the time of Mr McPherson's annual absence from the Fort in September, the register is complete for the autumn, winter, and spring months of three years, but the temperatures of the summer months were obtained in the year 1838 alone. In a paper which I published in the Journal of the Geographical Society (ix.) on Sir Edward Parry's Thermometrical Observations in the Arctic Regions, it is shewn that the mean of the temperatures at the hours 8 a.m. and 8 p.m. combined, does not differ more than three-tenths of a degree from the annual mean of the whole twenty-four hours at any of the places of observation, and is always in defect. I have, therefore, assumed the means of Mr McPherson's observations at these

two hours as giving very nearly the true annual mean. Having found, also, by consulting a considerable number of North American registers of temperature, that the hourly curve for September falls always between that of May and August, and generally somewhat nearer to the former than to the latter, I have supplied the defect of observations for that month by assuming + 48° F. as its mean heat.

The thermometer employed was a spirit one made by Carey, which, when compared with several constructed by Newman, was found to keep nearest the mean of the whole. No correction has been made for the diminishing contraction of the spirit at low temperatures.

Abstract of the Thermometrical Register kept at Fort Simpson for one year 1837-38. (The temperature for September interpolated.) (Spirit Thermometer by Carey. Fahr. Scale.)

MONTHS AND SEASONS.	Mean Heat in the Shade (Fahr.)			
	At 8 A. M.	At 2 P. M.	At 8 P. M.	8 A. M. 8 P. M.
1837.				
September, . .	+ 46.000	+ 60.000	+ 55.000	+ 48.000
October, . . .	+ 20.294	+ 28.470	+ 25.882	+ 23.088
November, . . .	+ 6.700	+ 11.300	+ 12.133	+ 9.417
December, . . .	- 10.387	- 9.613	- 9.935	- 10.161
1838.				
January, . . .	- 21.258	- 18.419	- 18.419	- 19.839
February, . . .	- 9.321	- 5.000	- 5.214	- 7.268
March,	- 8.064	+ 2.484	+ 1.452	- 3.306
April,	+ 17.933	+ 32.000	+ 29.367	+ 23.650
May,	+ 44.903	+ 54.806	+ 49.516	+ 47.210
June,	+ 62.067	+ 73.400	+ 64.933	+ 63.500
July,	+ 55.871	+ 70.613	+ 65.419	+ 60.806
August,	+ 48.501	+ 65.871	+ 57.742	+ 53.161
Whole Year, . .	+ 21.228	+ 30.636	+ 27.064	+ 24.146
Autumn.				
September—November,	+ 24.267	+ 33.204	+ 29.303	+ 26.795
Winter.				
December—February,	- 13.800	- 11.211	- 11.389	- 12.594
Spring.				
March—May, . . .	+ 18.261	+ 29.763	+ 26.750	+ 22.502
Summer.				
June—August, . .	+ 55.436	+ 69.924	+ 62.783	+ 59.109
By adding a quarter of a degree to the mean heat at 8 A. M. and 8 P. M. combined, the mean heat of the year 1837-38 is estimated to be nearly + 24½° F.				

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Abstract of the Thermometrical Register kept at Fort Simpson in the years 1837-38 and 1838-39. (Means of two successive years.) (Temperature for September interpolated in calculating the Mean Temperature of Autumn.)

MONTHS AND SEASONS.	Mean Heat in the Shade.			
	At 8 A. M.	At 2 P. M.	At 8 P. M.	At 8 A. M. & 8 P. M.
1837-38.				
October, . . .	+ 20.977	+ 30.080	+ 26.479	+ 23.728
November, . . .	+ 8.034	+ 12.517	+ 12.034	+ 10.034
December, . . .	- 8.516	- 7.984	- 8.339	- 8.428
1838-39.				
January, . . .	- 20.855	- 17.548	- 18.129	- 19.493
February, . . .	- 6.857	- 1.679	- 2.089	- 4.473
March, . . .	- 4.403	+ 12.677	+ 7.065	+ 1.331
April, . . .	+ 23.583	+ 47.216	+ 34.900	+ 29.242
May, . . .	+ 41.993	+ 56.985	+ 50.612	+ 46.303
Autumn.				
September—November,	+ 24.959	+ 34.153	+ 29.471	+ 27.215
Winter.				
December—February,	- 12.250	- 9.317	- 9.747	- 11.000
Spring.				
March—May, . . .	+ 20.356	+ 38.892	+ 30.815	+ 25.586
The mean heat of these two years, including the single summer of 1838, obtained by making a small addition to the mean of 8 A. M. and 8 P. M. combined, is a little above + 25½° F.				

Abstracts of the Thermometrical Register kept at Fort Simpson in 1837-8, 1838-9, and 1839-40. (Means of three successive years.) (September interpolated in calculating the Mean Autumn Heat.)

MONTHS AND SEASONS.	Mean Heat in the Shade.		
	8 A. M.	8 P. M.	8 A. M.—8 P. M.
1837-38-39.			
October, . . .	+ 20.726	+ 25.674	+ 23.200
November, . . .	+ 5.866	+ 9.166	+ 7.517
December, . . .	- 9.409	- 9.032	- 9.221
1838-39-40.			
January, . . .	- 14.409	- 12.505	- 13.457
February, . . .	- 12.306	- 8.553	- 10.429
March, . . .	+ 0.204	+ 8.742	+ 4.473
April, . . .	+ 22.055	+ 29.833	+ 25.944
May, . . .	+ 44.605	+ 51.168	+ 47.886
Autumn.			
September—November,	+ 24.160	+ 26.251	+ 26.206
Winter.			
December—February,	- 12.033	- 10.074	- 11.054
Spring.			
March—May, . . .	+ 22.291	+ 29.915	+ 26.103
The mean temperature of these three years, calculated as in the preceding tables by using the summer heat of 1838, and adding a quarter of a degree for the defect of the mean of the pair of hours 8 and 8 is rather under + 25¼° F.			

